Differential/Cascode Amplifiers

For Communications and Industrial Equipment at Frequencies from DC to 120 MHz

Features:

- *Controlled for input offset voltage, input offset current, and input bias current (CA3028 series only)*
- *Balanced differential amplifier configuration with controlled constant-current source*
- *Single- and dual-ended operation*

Applications:

- *RF and IF amplifiers (differential or cascode)*
- *DC, audio, and sense amplifiers*
- *Converter in the commercial FM band*
- *Oscillator*
- *Mixer*
- *Limiter*
- *Companion Application Note, ICAN 5337 "Application of the CA3028 Integrated Circuit Amplifier in the HF and VHF Ranges." This note covers characteristics of different operating modes, noise performance, mixer, limiter, and amplifier design considerations.*

The CA3028A and CA3028B are differential/cascode amplifiers designed for use in communications and industrial equipment operating at frequencies from dc to 120 MHz.

The CA3028B is like the CA3028A but is capable of premium performance particularly in critical dc and differential amplifier applications requiring tight controls for input offset voltage, input offset current, and input bias current.

The CA3053 is similar to the CA3028A and CA3028B but is recommended for IF amplifier applications.

The CA3028A, CA3028B, and CA3053 are available in 8-lead packages as shown below. When ordering these devices, it is important to add the appropriate suffix letter to the device.

Package/Lead Options

SMALL OUTLINE (150 mil)	STRAIGHT LEAD TO-5	DUAL-IN-LINE FORMED-LEAD TO-5	DUAL-IN-LINE PLASTIC (MINI-DIP)
CA3028AM	CA3028A*	CA3028AS	CA3028AE
CA3028BM	CA3028B*	CA3028BS	CA3028BE
CA3053M	CA3053*	CA3053S	CA3053E

*Most types in a straight-lead TO-5 package carry a "T" suffix. This one does not. Order type number as shown.

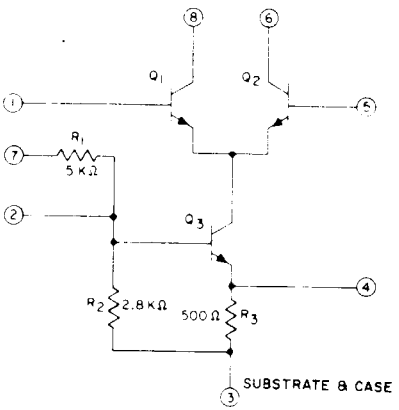


Figure 1 - Schematic diagram for CA3028A, CA3028B and CA3053.

ABSOLUTE MAXIMUM RATINGS at T_A = 25°C

DISSIPATION
- At T_A Up to 85°C (CA3028A, CA3028B, CA3053) ..... 450 mW
- At T_A 85°C (CA3028A, CA3028B, CA3053) ..... Derate linearly 5 mW/°C

AMBIENT-TEMPERATURE RANGE
- Operating ..... -55°C to +125°C
- Storage ..... -65°C to +150°C

LEAD TEMPERATURE (DURING SOLDERING)
- At distance 1/16 ± 1/32 (1.59 ± 0.79 mm) from case for 10 seconds max. ..... +265°C

MAXIMUM VOLTAGE RATINGS at T_A = 25°C

TERMINAL No.	1	2	3	4	5	6	7	8
1		0 to -15▲	0 to -15▲	0 to -15▲	+5 to -5	*	*	+20⊕ to 0
2			+5 to -11	+5 to -1	+15Φ to 0	*	+15Φ to 0	*
3‡				+10 to 0	+15Φ to 0	+30● to 0	+15Φ to 0	+30● to 0
4					+15Φ to 0	*	*	*
5						+20⊕ to 0	*	*
6							*	*
7								*
8								

This chart gives the range of voltages which can be applied to the terminals listed horizontally with respect to the terminals listed vertically. For example, the voltage range of the horizontal terminal 4 with respect to terminal 2 is -1 to +5 volts.

‡ Terminal #3 is connected to the substrate and case.

* Voltages are not normally applied between these terminals. Voltages appearing between these terminals will be safe, if the specified voltage limits between all other terminals are not exceeded.

▲ Limit is -12V for CA3053.

⊕ Limit is +15V for CA3053.

Φ Limit is +12V for CA3053.

● Limit is +24V for CA3028A and +18V for CA3053.

MAXIMUM CURRENT RATINGS

TERMINAL No.	I_{IN} mA	I_{OUT} mA
1	0.6	0.1
2	4	0.1
3	0.1	23
4	20	0.1
5	0.6	0.1
6	20	0.1
7	4	0.1
8	20	0.1

ELECTRICAL CHARACTERISTICS at T_A = 25°C

CHARACTERISTIC	SYMBOL	TEST CIRCUIT Fig.	SPECIAL TEST CONDITIONS		LIMITS TYPE CA3028A			LIMITS TYPE CA3028B			LIMITS TYPE CA3053			UNITS	TYPICAL CHARACTERISTICS CURVES Fig.
					Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.		
STATIC CHARACTERISTICS															
			$+V_{CC}$	$-V_{EE}$											
Input Offset Voltage	V_{IO}	2	6V 12V	6V 12V	- -	- -	- -	- -	0.98 0.89	5 5	- -	- -	- -	mV	4
Input Offset Current	I_{IO}	3a	6V 12V	6V 12V	- -	- -	- -	- -	0.56 1.06	5 6	- -	- -	- -	μA	4
Input Bias Current	I_I	3a	6V 12V	6V 12V	- -	16.6 36	70 106	- -	16.6 36	40 80	- -	- -	- -	μA	5a
		3b	9V 12V	-	- -	- -	- -	- -	- -	- -	- -	29 36	85 125		5b
Quiescent Operating Current	I_6 or I_8	3a	6V 12V	6V 12V	0.8 2	1.25 3.3	2 5	1 2.5	1.25 3.3	1.5 4	- -	- -	- -	mA	6a 7
		3b	9V 12V	-	- -	- -	- -	- -	- -	- -	1.2 2.0	2.2 3.3	3.5 5.0		6b
AGC Bias Current (Into Constant-Current Source Terminal No.7)	I_7	8a	12V 12V	V_{AGC} = +9 V_{AGC} = +12	- -	1.28 1.65	- -	- -	1.28 1.65	- -	- -	- -	- -	mA	8b
		-	9V 12V	-	- -	- -	- -	- -	- -	- -	- -	1.15 1.55	- -		-
Input Current (Terminal No.7)	I_7	-	6V 12V	6V 12V	0.5 1	0.85 1.65	1 2.1	0.5 1	0.85 1.65	1 2.1	- -	- -	- -	mA	-
Device Dissipation	P_T	3a	6V 12V	6V 12V	24 120	36 175	54 260	24 120	36 175	42 220	- -	- -	- -	mW	9
		3b	9V 12V	-	- -	- -	- -	- -	- -	- -	- -	50 100	80 150		-

ELECTRICAL CHARACTERISTICS at T_A = 25°C (cont'd)

CHARACTERISTIC	SYMBOL	TEST CIRCUIT Fig	SPECIAL TEST CONDITIONS		LIMITS TYPE CA3028A Min	Typ	Max	LIMITS TYPE CA3028B Min	Typ	Max	LIMITS TYPE CA3053 Min	Typ	Max	UNITS	TYPICAL CHARACTERISTICS CURVE Fig
DYNAMIC CHARACTERISTICS															
Power Gain	G_P	10a	f = 100 MHz	Cascode	16	20		16	20					dB	10b
		11a,d	V_{CC} = +9V	Diff. Ampl.	14	17		14	17						11b,e
		10a	f = 10.7 MHz	Cascode	35	39		35	39		35	39		dB	10b *
		11a	V_{CC} = +9V	Diff. Ampl.	28	32		28	32		28	32			11b *
Noise Figure	NF	10a	f = 100 MHz	Cascode		7.2	9		7.2	9				dB	10c
		11a,d	V_{CC} = +9V	Diff. Ampl.		6.7	9		6.7	9					11c,e
Input Admittance	Y_{11}		f = 10.7 MHz V_{CC} = +9V	Cascode					0.6 + j 1.6					mmho	12
				Diff. Ampl.					0.5 + j 0.5						13
Reverse Transfer Admittance	Y_{12}			Cascode					0.0003 − j0					mmho	14
				Diff. Ampl.					0.01 − j0.0002						15
Forward Transfer Admittance	Y_{21}			Cascode					99 − j18					mmho	16
				Diff. Ampl.					37 + j0.5						17
Output Admittance	Y_{22}			Cascode					0 + j0.08					mmho	18
				Diff. Ampl.					0.04 + j0.23						19
Power Output (Untuned)	P_o	20a	f = 10.7 MHz	Diff. Ampl. 50 Ω Input Output		5.7			5.7					μW	20b
AGC Range Max Power Gain to Full Cutoff	AGC	21a	V_{CC} = +9V	Diff. Ampl.		62			62					dB	21b
Voltage Gain at f = 10.7 MHz	A	22a	f = 10.7 MHz V_{CC} = +9V R_L = 1 kΩ	Cascode		40			40			40		dB	22b
		22c		Diff. Ampl.		30			30			30			22d
Voltage Gain Differential at f = 1 kHz	A	23	V_{CC} = +6V, V_{EE} = 6V, R_L = 2 kΩ					35	38	42				dB	
			V_{CC} = +12V, V_{EE} = 12V, R_L = 1.6 kΩ					40	42.5	45					
Max. Peak to Peak Output Voltage at f = 1 kHz	V_o(P-P)	23	V_{CC} = +6V, V_{EE} = 6V, R_L = 2 kΩ					7	11.5					V_{P-P}	
			V_{CC} = +12V, V_{EE} = 12V, R_L = 1.6 kΩ					15	23						
Bandwidth at 3 dB point	BW	23	V_{CC} = +6V, V_{EE} = 6V, R_L = 2 kΩ						7.3					MHz	
			V_{CC} = +12V, V_{EE} = 12V, R_L = 1.6 kΩ						8						
Common-Mode Input Voltage Range	V_{CMR}	24	V_{CC} = +6V, V_{EE} = 6V					-2.5	(-3.2, 4.5)	4				V	
			V_{CC} = +12V, V_{EE} = 12V					-5	(-7, 9)	7					
Common-Mode Rejection Ratio	CMR	24	V_{CC} = +6V, V_{EE} = 6V					60	110					dB	
			V_{CC} = +12V, V_{EE} = 12V					60	90						
Input Impedance at f = 1 kHz	Z_{IN}		V_{CC} = +6V, V_{EE} = 6V						5.5					kΩ	
			V_{CC} = +12V, V_{EE} = 12V						3						
Peak-to-Peak Output Current	I_{P-P}		V_{CC} = +9V	f = 10.7 MHz e_{in} = 400 mV Diff.-Ampl.	2	4	7	2.5	4	6	2	4	7	mA	
			V_{CC} = +12V		3.5	6	10	4.5	6	8	3.5	6	10		

* Does not apply to CA3053

6 DIFFERENTIAL AMPLIFIERS

DEFINITION OF TERMS

AGC Bias Current

The current drawn by the device from the AGC-voltage source, at maximum AGC voltage.

AGC Range

The total change in voltage gain (from maximum gain to complete cutoff) which may be achieved by application of the specified range of dc voltage to the AGC input terminal of the device.

Common-Mode Rejection Ratio

The ratio of the full differential voltage gain to the common-mode voltage gain.

Device Dissipation

The total power drain of the device with no signal applied and no external load current.

Input Bias Current

The average value (one-half the sum) of the currents at the two input terminals when the quiescent operating voltages at the two output terminals are equal.

Input Offset Current

The difference in the currents at the two input terminals when the quiescent operating voltages at the two output terminals are equal.

Input Offset Voltage

The difference in the dc voltages which must be applied to the input terminals to obtain equal quiescent operating voltages (zero output offset voltage) at the output terminals.

Noise Figure

The ratio of the total noise power of the device and a resistive signal source to the noise power of the signal source alone, the signal source representing a generator of zero impedance in series with the source resistance.

Power Gain

The ratio of the signal power developed at the output of the device to the signal power applied to the input, expressed in dB.

Quiescent Operating Current

The average (dc) value of the current in either output terminal.

Voltage Gain

The ratio of the change in output voltage at either output terminal with respect to ground, to a change in input voltage at either input terminal with respect to ground, with the other input terminal at ac ground.

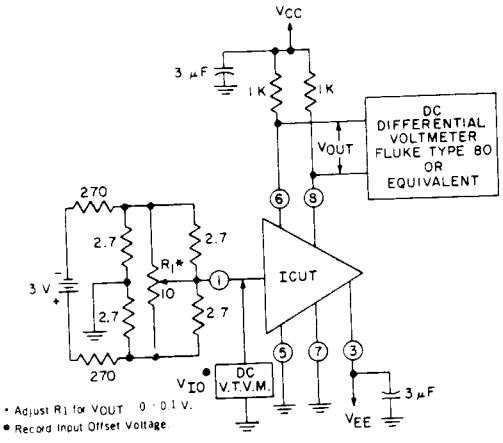


Fig. 2 - Input offset voltage test circuit for CA3028B.

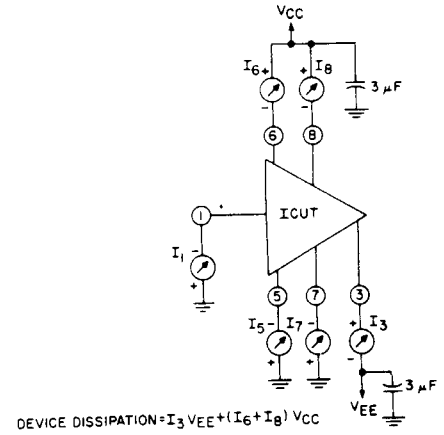


Fig. 3a - Input offset current, input bias current, device dissipation, and quiescent operating current test circuit for CA3028A and CA3028B.

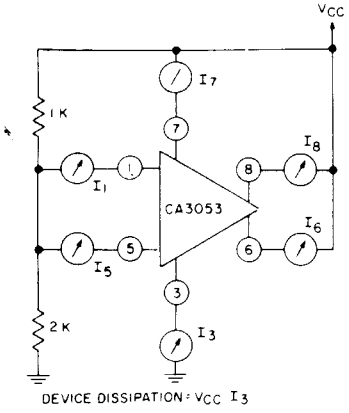


Fig. 3b – Input bias current, device dissipation and quiescent operating current test circuit for CA3053.

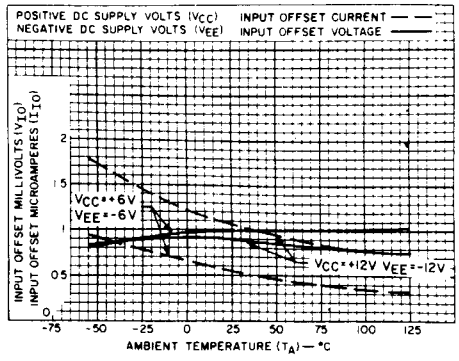


Fig. 4 – Input offset voltage and input offset current for CA3028B.

TYPICAL CHARACTERISTICS

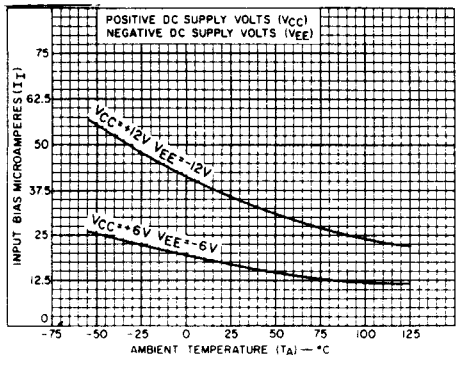


Fig. 5a – Input bias current vs. ambient temperature for CA3028A and CA3028B.

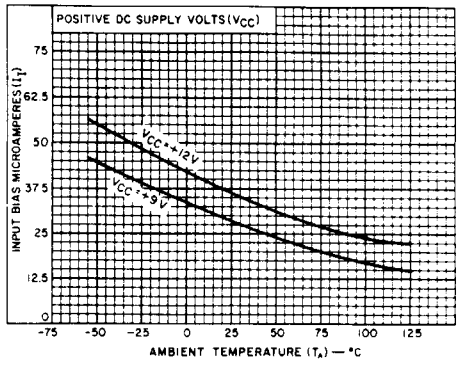


Fig. 5b – Input bias current vs. ambient temperature for CA3053.

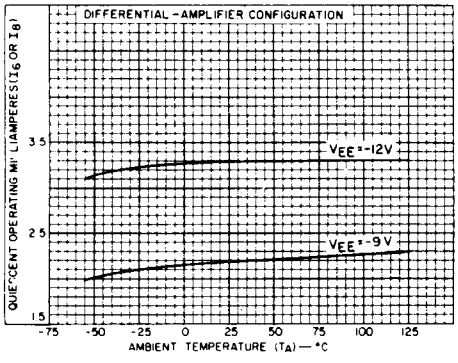


Fig. 6a – Quiescent operating current vs. ambient temperature for CA3028A and CA3028B.

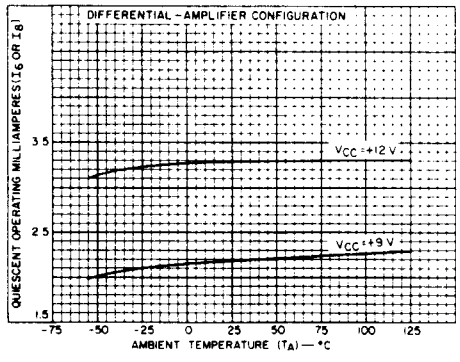


Fig. 6b – Quiescent operating current vs. ambient temperature for CA3053.

TYPICAL CHARACTERISTICS (Continued)

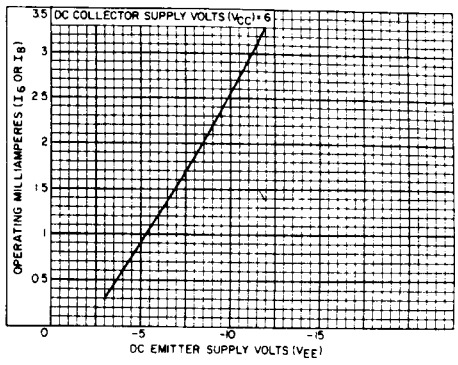


Fig. 7 - Operating current vs. V_{EE} voltage for CA3028A and CA3028B.

TYPICAL CHARACTERISTICS AND TEST CIRCUITS

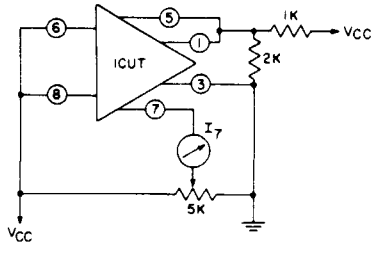


Fig. 8a - AGC bias current test circuit (differential-amplifier configuration) for CA3028A and CA3028B.

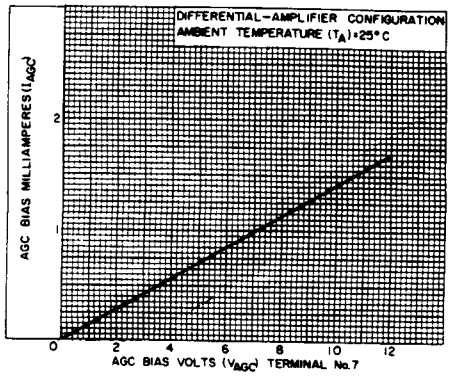


Fig. 8b - AGC bias current vs. bias volts (terminal No. 7) for CA3028A and CA3028B.

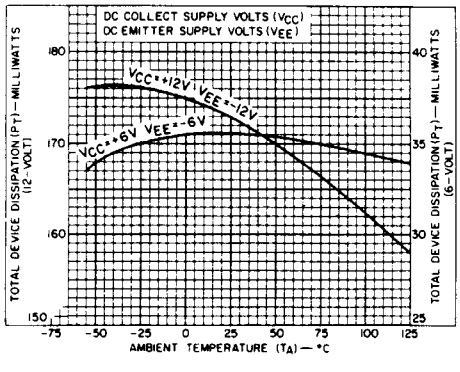
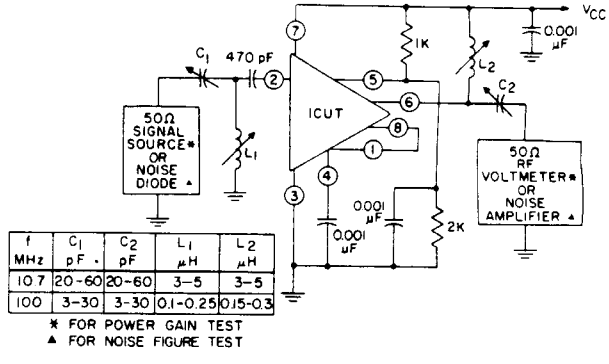

DC COLLECT SUPPLY VOLTS (VCC)
DC EMITTER SUPPLY VOLTS (VEE)
VCC=+12V VEE=-12V
VCC=+6V VEE=-6V
TOTAL DEVICE DISSIPATION (PT) — MILLIWATTS (12-VOLT)
TOTAL DEVICE DISSIPATION (PT) — MILLIWATTS (6-VOLT)
AMBIENT TEMPERATURE (TA) — °C

Fig. 9 - Device dissipation vs. temperature for CA3028A and CA3028B.



f MHz	C1 pF	C2 pF	L1 µH	L2 µH
10.7	20-60	20-60	3-5	3-5
100	3-30	3-30	0.1-0.25	0.15-0.3

* FOR POWER GAIN TEST
▲ FOR NOISE FIGURE TEST

Fig. 10a - Power gain and noise figure test circuit (cascode configuration) for CA3028A, CA3028B and CA3053.*

** 10.7 MHz Power Gain Test Only.*

TYPICAL CHARACTERISTICS AND TEST CIRCUITS (Continued)

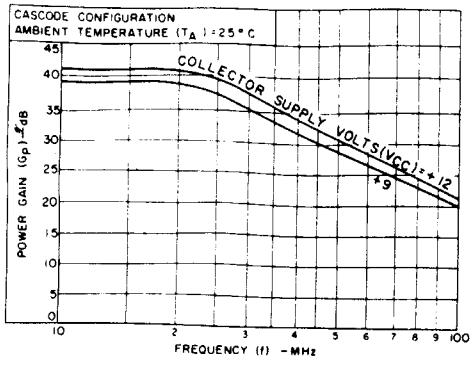


Fig. 10b - Power gain vs. frequency (cascode configuration) for CA3028A and CA3028B.

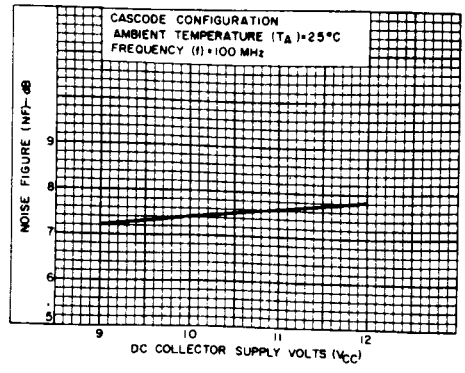
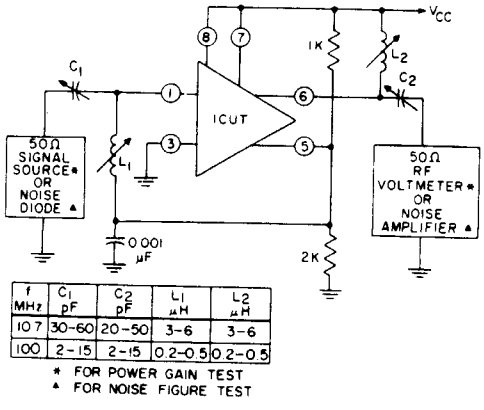


Fig. 10c - 100 MHz noise figure vs. collector supply volts (cascode configuration) for CA3028A and CA3028B.

TYPICAL NOISE FIGURE AND POWER GAIN TEST CIRCUITS AND CHARACTERISTICS



f MHz	C1 pF	C2 pF	L1 μH	L2 μH
10.7	30-60	20-50	3-6	3-6
100	2-15	2-15	0.2-0.5	0.2-0.5

* FOR POWER GAIN TEST
▲ FOR NOISE FIGURE TEST

Fig. 11a - Power gain and noise figure test circuit (differential-amplifier configuration and terminal No. 7 connected to V_{CC}) for CA3028A, CA3028B and CA3053*

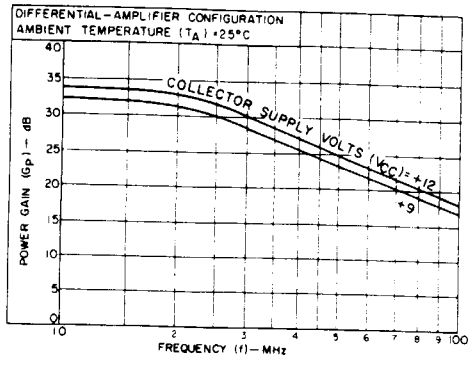


Fig. 11b - Power gain vs. frequency (differential-amplifier configuration) for CA3028A and CA3028B.

* 10.7 MHz Power Gain Test Only.

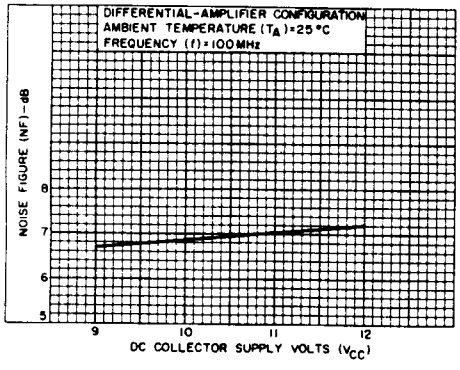
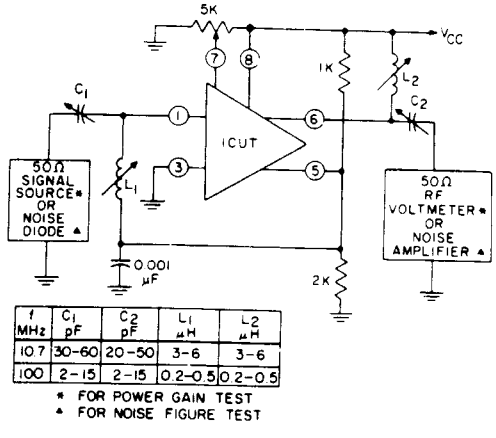

DIFFERENTIAL-AMPLIFIER CONFIGURATION
AMBIENT TEMPERATURE (TA) = 25°C
FREQUENCY (f) = 100 MHz
NOISE FIGURE (NF) — dB
DC COLLECTOR SUPPLY VOLTS (VCC)

Fig. 11c - 100 MHz noise figure vs. collector supply voltage (differential-amplifier configuration) for CA3028A and CA3028B.



f MHz	C1 pF	C2 pF	L1 μH	L2 μH
10.7	30-60	20-50	3-6	3-6
100	2-15	2-15	0.2-0.5	0.2-0.5

* FOR POWER GAIN TEST
▲ FOR NOISE FIGURE TEST

Fig. 11d - Power gain and noise figure test circuit (differential-amplifier configuration) for CA3028A and CA3028B.

TYPICAL NOISE FIGURE AND POWER GAIN TEST CIRCUITS AND CHARACTERISTICS (Continued)

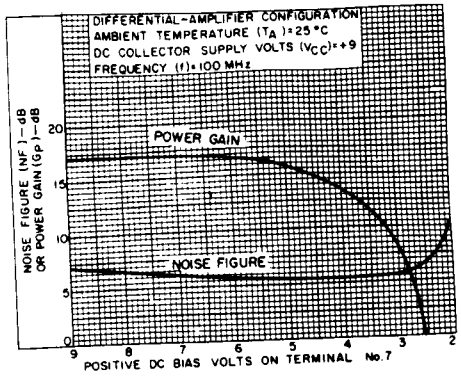

DIFFERENTIAL-AMPLIFIER CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
DC COLLECTOR SUPPLY VOLTS (V_{CC}) = +9
FREQUENCY (f) = 100 MHz
POWER GAIN
NOISE FIGURE
NOISE FIGURE (NF) — dB
OR POWER GAIN (G_P) — dB
POSITIVE DC BIAS VOLTS ON TERMINAL No.7

Fig. 11e - 100 MHz noise figure and power gain vs. base-to-emitter bias (terminal No. 7) for CA3028A and CA3028B.

TYPICAL ADMITTANCE PARAMETERS

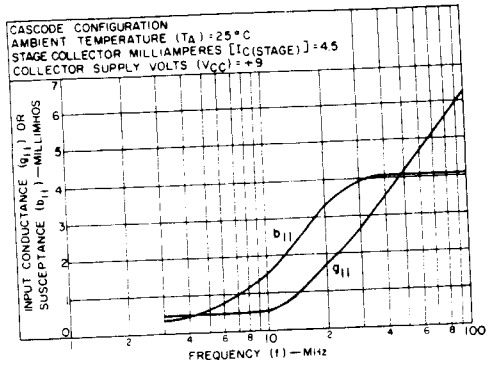

CASCODE CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
STAGE COLLECTOR MILLIAMPERES [$I_{C(STAGE)}$] = 4.5
COLLECTOR SUPPLY VOLTS (V_{CC}) = +9
INPUT CONDUCTANCE (g_{11}) OR SUSCEPTANCE (b_{11}) — MILLIMHOS
b_{11}
g_{11}
FREQUENCY (f) — MHz

Fig. 12 - Input admittance (Y_{11}) vs. frequency (cascode configuration) for CA3028A, CA3028B and CA3053.

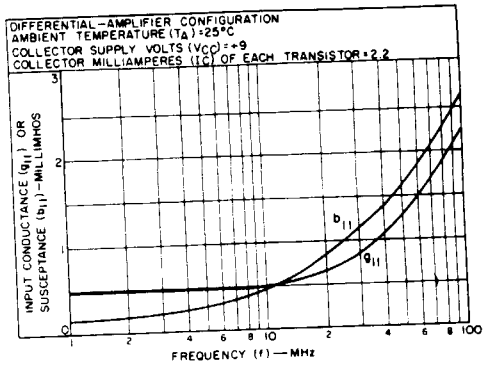

DIFFERENTIAL-AMPLIFIER CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
COLLECTOR SUPPLY VOLTS (V_{CC}) = +9
COLLECTOR MILLIAMPERES (I_C) OF EACH TRANSISTOR = 2.2
INPUT CONDUCTANCE (g_{11}) OR SUSCEPTANCE (b_{11}) — MILLIMHOS
b_{11}
g_{11}
FREQUENCY (f) — MHz

Fig. 13 - Input admittance (Y_{11}) vs. frequency (differential-amplifier configuration) for CA3028A, CA3028B and CA3053.

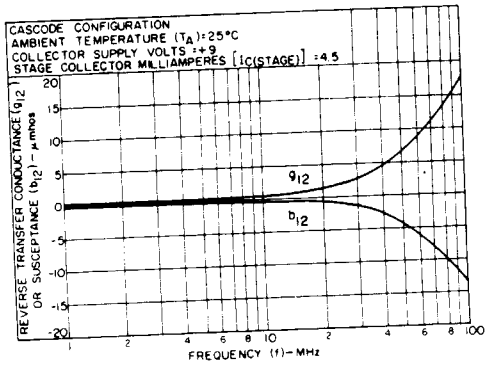

CASCODE CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
COLLECTOR SUPPLY VOLTS = +9
STAGE COLLECTOR MILLIAMPERES [$I_{C(STAGE)}$] = 4.5
REVERSE TRANSFER CONDUCTANCE (g_{12}) OR SUSCEPTANCE (b_{12}) — μmhos
g_{12}
b_{12}
FREQUENCY (f) — MHz

Fig. 14 - Reverse transadmittance (Y_{12}) vs. frequency (cascode configuration) for CA3028A, CA3028B and CA3053.

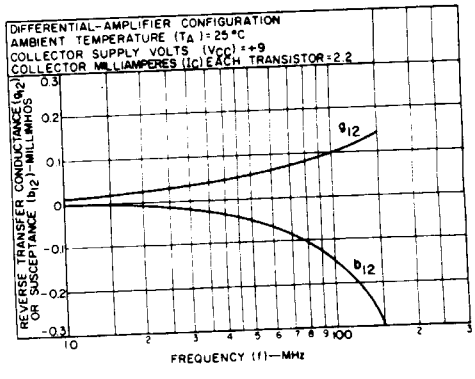

DIFFERENTIAL-AMPLIFIER CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
COLLECTOR SUPPLY VOLTS (V_{CC}) = +9
COLLECTOR MILLIAMPERES (I_C) EACH TRANSISTOR = 2.2
REVERSE TRANSFER CONDUCTANCE (g_{12}) OR SUSCEPTANCE (b_{12}) — MILLIMHOS
g_{12}
b_{12}
FREQUENCY (f) — MHz

Fig 15 - Reverse transadmittance (Y_{12}) vs. frequency (differential-amplifier configuration) for CA3028A, CA3028B and CA3053.

TYPICAL ADMITTANCE PARAMETERS (Continued)

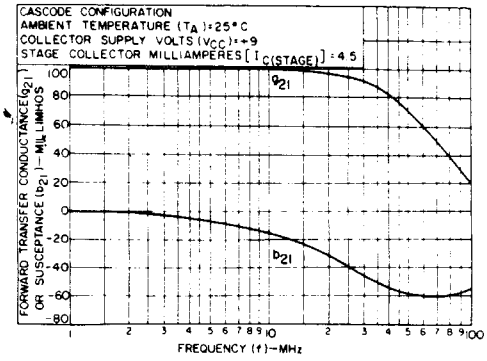

CASCODE CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
COLLECTOR SUPPLY VOLTS (V_{CC}) = +9
STAGE COLLECTOR MILLIAMPERES [$I_{C(STAGE)}$] = 4.5
FORWARD TRANSFER CONDUCTANCE (g_{21}) OR SUSCEPTANCE (b_{21}) — MILLIMHOS
g_{21}
b_{21}
FREQUENCY (f) — MHz

Fig. 16 - Forward transadmittance (Y_{21}) vs. frequency (cascode configuration) for CA3028A, CA3028B and CA3053.

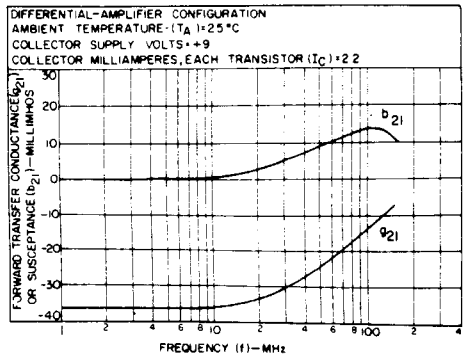

DIFFERENTIAL-AMPLIFIER CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
COLLECTOR SUPPLY VOLTS = +9
COLLECTOR MILLIAMPERES, EACH TRANSISTOR (I_C) = 2.2
FORWARD TRANSFER CONDUCTANCE (g_{21}) OR SUSCEPTANCE (b_{21}) — MILLIMHOS
b_{21}
g_{21}
FREQUENCY (f) — MHz

Fig. 17 - Forward transadmittance (Y_{21}) vs. frequency (differential-amplifier configuration) for CA3028A, CA3028B and CA3053.

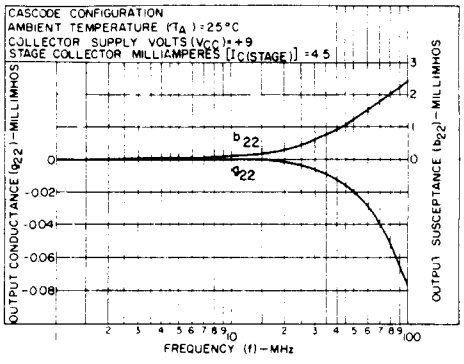


Fig. 18 - Output admittance (Y_{22}) vs. frequency (cascode configuration) for CA3028A, CA3028B and CA3053.

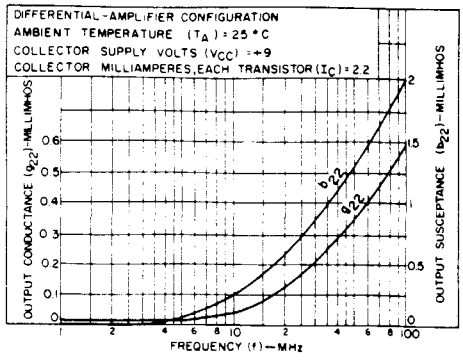

DIFFERENTIAL-AMPLIFIER CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
COLLECTOR SUPPLY VOLTS (V_{CC}) = +9
COLLECTOR MILLIAMPERES, EACH TRANSISTOR (I_C) = 2.2
OUTPUT CONDUCTANCE (g_{22}) — MILLIMHOS
OUTPUT SUSCEPTANCE (b_{22}) — MILLIMHOS
b_{22}
g_{22}
FREQUENCY (f) — MHz

Fig. 19 - Output admittance (Y_{22}) vs. frequency (differential-amplifier configuration) for CA3028A, CA3028B and CA3053.

TYPICAL TEST CIRCUITS AND CHARACTERISTICS

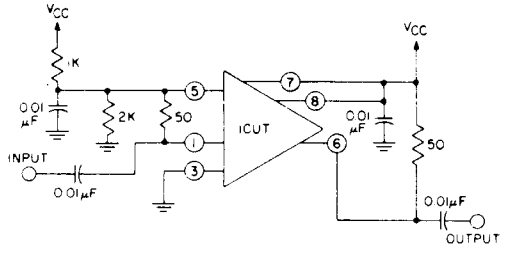


Fig. 20a - Output power test circuit for CA3028A and CA3028B.

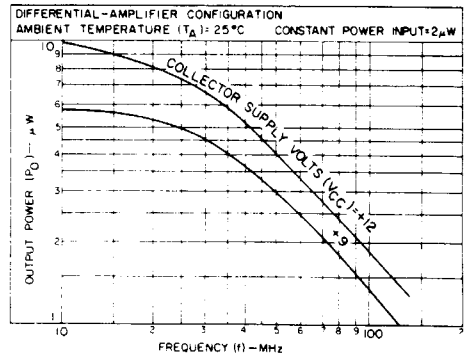
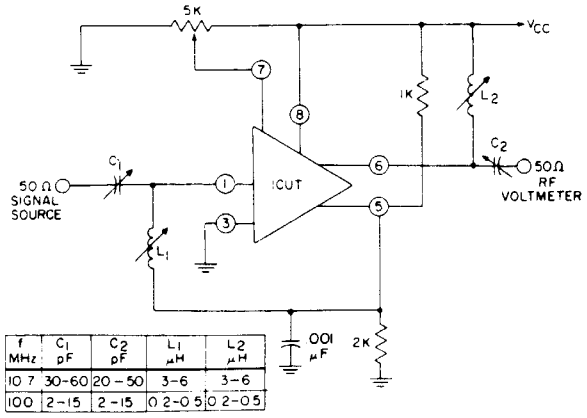

DIFFERENTIAL-AMPLIFIER CONFIGURATION
AMBIENT TEMPERATURE (T_A) = 25°C
CONSTANT POWER INPUT = 2 μW
COLLECTOR SUPPLY VOLTS (V_{CC}) = +12
+9
OUTPUT POWER (P_O) — μW
FREQUENCY (f) — MHz

Fig. 20b - Output power vs. frequency - 50 Ω input and 50 Ω output (differential-amplifier configuration) for CA3028A and CA3028B.

TYPICAL TEST CIRCUITS AND CHARACTERISTICS (Continued)



f MHz	C_1 pF	C_2 pF	L_1 μH	L_2 μH
10.7	30-60	20-50	3-6	3-6
100	2-15	2-15	0.2-0.5	0.2-0.5

Fig. 21a - AGC range test circuit (differential amplifier) for CA3028A and CA3028B.

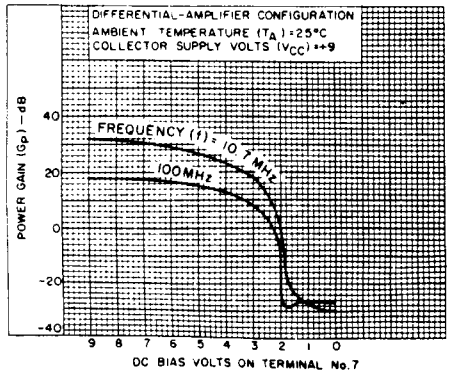


Fig. 21b - AGC characteristics for CA3028A and CA3028B.

TEST CIRCUITS AND TYPICAL CHARACTERISTICS

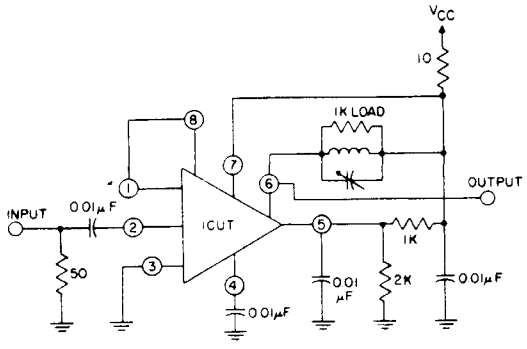


Fig. 22a - Transfer characteristic (voltage gain) test circuit (10.7 MHz) cascode configuration for CA3028A, CA3028B and CA3053.

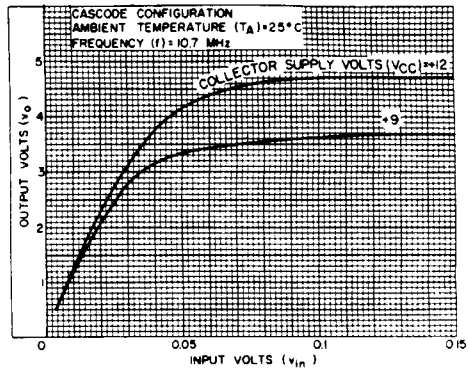


Fig. 22b - Transfer characteristics (cascode configuration) for CA3028A, CA3028B and CA3053.

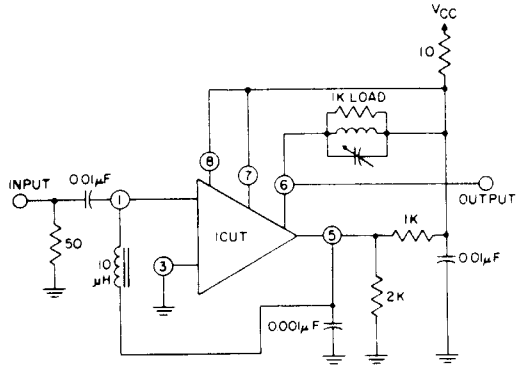


Fig. 22c - Transfer characteristic (voltage gain) test circuit (10.7 MHz) differential-amplifier configuration for CA3028A, CA3028B and CA3053.

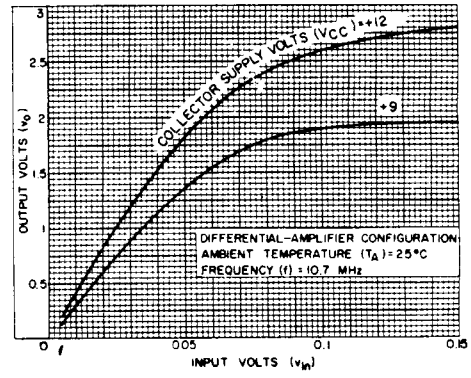
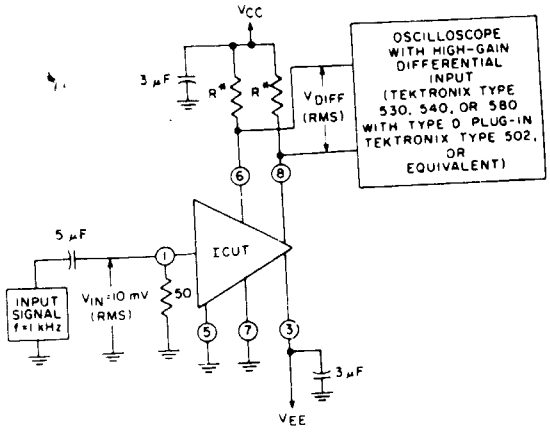


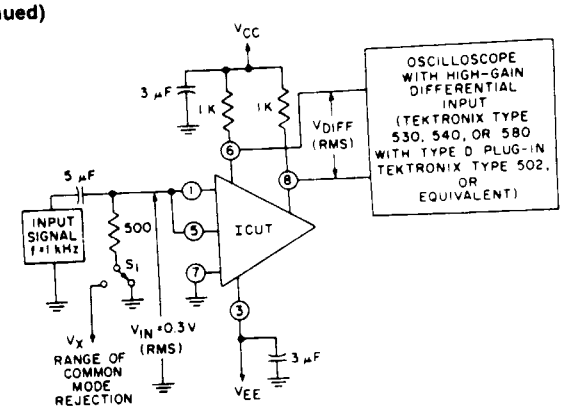
Fig. 22d - Transfer characteristics (differential-amplifier configuration) for CA3028A, CA3028B and CA3053.

TEST CIRCUITS AND TYPICAL CHARACTERISTICS (Continued)



* For R = 1.6 kΩ – (V_{CC} = 12V, V_{EE} = -12V)
For R = 2 kΩ – (V_{CC} = 6V, V_{EE} = -6V)

Fig. 23 - Differential voltage gain, maximum peak-to-peak output voltage, and bandwidth test circuit for CA3028B.



For CMR test: S_1 to ground
For input common-mode voltage range test: S_1 to V_X

Common mode rejection ratio = $20 \log_{10} \frac{(A^*)(2)(0.3)}{V_{DIFF\,(RMS)}}$

* A = Single-ended voltage gain.

Fig. 24 - Common-mode rejection ratio and common-mode input-voltage range test circuit for CA3028B.

6 DIFFERENTIAL AMPLIFIERS